

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

(NASA-CR-151215) INTERNAL FRICTION Q FACTOR
MEASUREMENTS IN LUNAR ROCKS Annual Report,
1 Feb. - 31 Dec. 1976 (Rockwell
International Science Center) 5 p HC A02/ME
A01 CSCL 03B G3/91

N77-19971

Unclass
20496

1

CR 151215

February 1977

SC577.38AR

INTERNAL FRICTION Q FACTOR MEASUREMENTS
IN LUNAR ROCKS

ANNUAL REPORT NO. 3

For Period 02/01/76 thru 12/31/76

Contract No. NAS9-13846

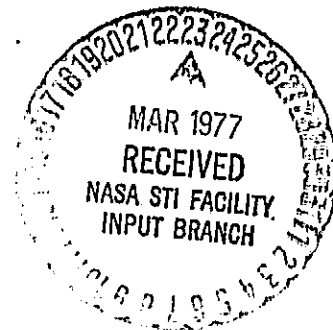
General Order No. 577

Prepared for:

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Science and Applications Directorate
Houston, Texas 77058

by:

B. R. Tittmann
B. R. Tittmann
Principal Investigator



This work was sponsored by the National Aeronautics and Space Administration. Reproduction in whole or in part is permitted for any purpose of the United States Government.



Science Center
Rockwell International

1049 CAMINO DOS RIOS
THOUSAND OAKS, CALIF. 91320
805/438-4545

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INTERNAL FRICTION Q FACTOR MEASUREMENTS IN LUNAR ROCKS - ANNUAL REPORT NO. 3		5. TYPE OF REPORT & PERIOD COVERED Annual Report 02/01/76 thru 12/31/76
7. AUTHOR(s) B. R. Tittmann		6. PERFORMING ORG. REPORT NUMBER SC577.38AR
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science Center, Rockwell International 1049 Camino Dos Rios Thousand Oaks, CA 91360		8. CONTRACT OR GRANT NUMBER(s) NAS9-13846
11. CONTROLLING OFFICE NAME AND ADDRESS National Aeronautics and Space Administration Lyndon B. Johnson Space Center Houston, Texas 77058		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE February 1977
		13. NUMBER OF PAGES 5
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Reproduction in whole or in part is permitted for any purpose of the United States Government.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Quality-factor Q, confining pressure, basalt, volatiles, attenuation, seismic waves, terrestrial analog, adsorbed H ₂ O, internal friction, damping, absorption, vacuum, outgassing.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) To aid in the interpretation of seismic data obtained <u>below</u> the lunar surface we report here on measurements under confining pressures with the sample encapsulated under hard vacuum. Since partial crack closure would be expected to occur already at low pressures, as evidenced by the well-known and dramatic increases in velocity with increasing pressure in the 0.5 kbar range, we have been concentrating our Q measurements in this range. In these experiments we have been able to achieve a Q value just under 2000 at 0.5 kbar		

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

for a terrestrial analog of lunar basalt. We have also found that in contrast to the modulus which increases by as much as 10%, the quality factor Q shows little or no change with pressure, i.e., a well-outgassed sample maintains a high Q , whereas one exposed to laboratory atmosphere maintains a low Q . This result suggests that the absence of volatiles plays an important role in determining the Q factor even at a depth of 10 km below the lunar surface.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)



SC577.38AR

QUALITY FACTOR Q UNDER CONFINING PRESSURE; B. R. Tittmann,
L. Ahlberg, and H. Nadler; Science Center, Rockwell International,
1049 Camino Dos Rios, Thousand Oaks, CA 91360

We have recently reported the discovery that small amounts of adsorbed volatiles can have a profound effect on the Q of rocks and other porous media (1). We have obtained room temperature Q values in excess of several thousand in lunar sample 70215,85 and in strongly outgassed analogs of lunar basalt. The effect is reversible in that re-exposure to laboratory atmosphere restores the Q to its original low value of $Q \approx 100$ (2). Experiments carried out with a low-strain, low-frequency apparatus at 50 Hz show similar increases of Q with outgassing, thus providing evidence that these changes in Q can be expected to be important at seismic frequencies. These results help explain the contrast between seismic data in the lunar and terrestrial near-surface regions in terms of the absence and presence, respectively, of adsorbed H_2O .

To aid in the interpretation of seismic data obtained below the lunar surface (3,4) we report here on measurements under confining pressures with the sample encapsulated under hard vacuum. Since partial crack closure would be expected to occur already at low pressures as evidenced by the well-known and dramatic increases in velocity with increasing pressure in the 0.5 kbar range - see, for example, ref. (5) - we have been concentrating our Q measurements in this range. In these experiments we have been able to achieve a Q value just under 2000 at 0.5 kbar for a terrestrial analog of lunar basalt. We have also found that in contrast to the modulus which increases by as much as 10%, the quality factor Q shows little or no change with pressure, i.e., a well-outgassed sample maintains a high Q, whereas one exposed to laboratory atmosphere maintains a low Q. This result suggests that the absence of volatiles plays an important role in determining the Q factor even at a depth of 10 km below the lunar surface.

In the experiments, we have been using samples of fine-grained basalt with about 1.0% open-pore porosity from an exposed dike in the Santa Monica Mountains in Southern California. In the sample preparation we have found the following procedure most useful. After initial saw cuts, the samples are gently ground into round cylinders 12.7 cm long, 1.0 cm radius. After thorough cleaning and outgassing described previously (6), they are then inserted into 4 mil wall seamless Cu tubing which is first heated so that upon cooling it shrinks down tightly against the rock. The sheathed samples and their end caps are then outgassed as before and mounted under dry He gas in the welding chamber where they are held at 1×10^{-5} torr for 12 hours. At this point an electron beam is applied to seal the seam between the tube and the end cap. Repeated exposure of the samples so prepared to confining pressures show no deleterious effects on the seam and no anomalous decreases in velocity due to leaks in the sheath, so that the vacuum inside the capsule appears to be maintained intact. In order to lower the operating frequency of the encapsulated sample as much as conveniently possible, the sample is



SC577.38AR

end-loaded by using a solid Cu plug for the end-cap. In this way, the resonant frequency is lowered from the 10 kHz to the 1 kHz range. The resonant vibration is now analyzed in terms of a composite oscillator and the modulus is calculated from the observed resonant frequency of the composite oscillator and the known or measured moduli and densities of the unclad rock and Cu plugs.

Experimental Results. The ideal way to make a quantitative comparison between a thoroughly outgassed sample and a sample exposed to the atmosphere is to make the measurements on the same sample under the two different conditions. Although this appears difficult because of the vacuum encapsulation process, we have found the following approach useful. We first encapsulate the sample in the outgassed state as described above, and proceed with the pressure runs. Then the Cu end-caps are drilled, tapped, and, after the sample is exposed for 48 hrs to laboratory air, are fitted with tightly fitting Cu inserts which are threaded and bonded into place. Upon hardening of the bond, the sample is checked for leaks and the pressure runs are carried out.

Figure 1 gives an example of one of several experiments carried out for the sample in torsional resonance and is typical for the pressure dependence of the Q-factor in both the "outgassed" and "laboratory air exposed" states. After initial gentle rises in Q with pressure, the curves are seen to level off (with slightly lower Q at the higher pressures). This behavior is completely different from the pressure dependence of the shear modulus which in a characteristic manner shows a dramatic rise with pressure of up to 10% over the same range of pressures. This result suggests that the partial closing of cracks does not affect the Q nearly as strongly as it does the stiffness of the rock and that adsorbed H₂O is still likely to play a role in determining the Q even at some depth below the surface. The highest Q achieved in these runs was $Q \approx 1800$, which is nearly the same as the high Q values previously achieved with well outgassed, unclad terrestrial analogs at zero confining pressure.

References

- (1) Tittmann, B. R., Housley, R. M., and Cirlin, E. H. (1974), Proc. Lunar Sci. Conf. 5th, p. 2631.
- (2) Tittmann, B. R., Curnow, J. M., and Housley, R. M. (1975), Proc. Lunar Sci. Conf. 6th, p. 3217-3226.
- (3) Dainty, A. M., Toksöz, M. N., and Stein, S. (1976), Proc. Lunar Sci. Conf. 7th, p. 3057-3073.
- (4) Nakamura, Y., Latham, G. V., Dorman, H. J., and Duennebier, F. K. (1976), Proc. Lunar Sci. Conf. 7th, p. 3113-3121.
- (5) Mizutani, H., and Newbigging, D. F. (1973), Proc. Lunar Sci. Conf. 4th, p. 2601-2609.
- (6) Tittmann, B. R., Ahlberg, L., and Curnow, J. (1976), Proc. Lunar Sci. Conf. 7th, p. 3123.

SC577.38AR

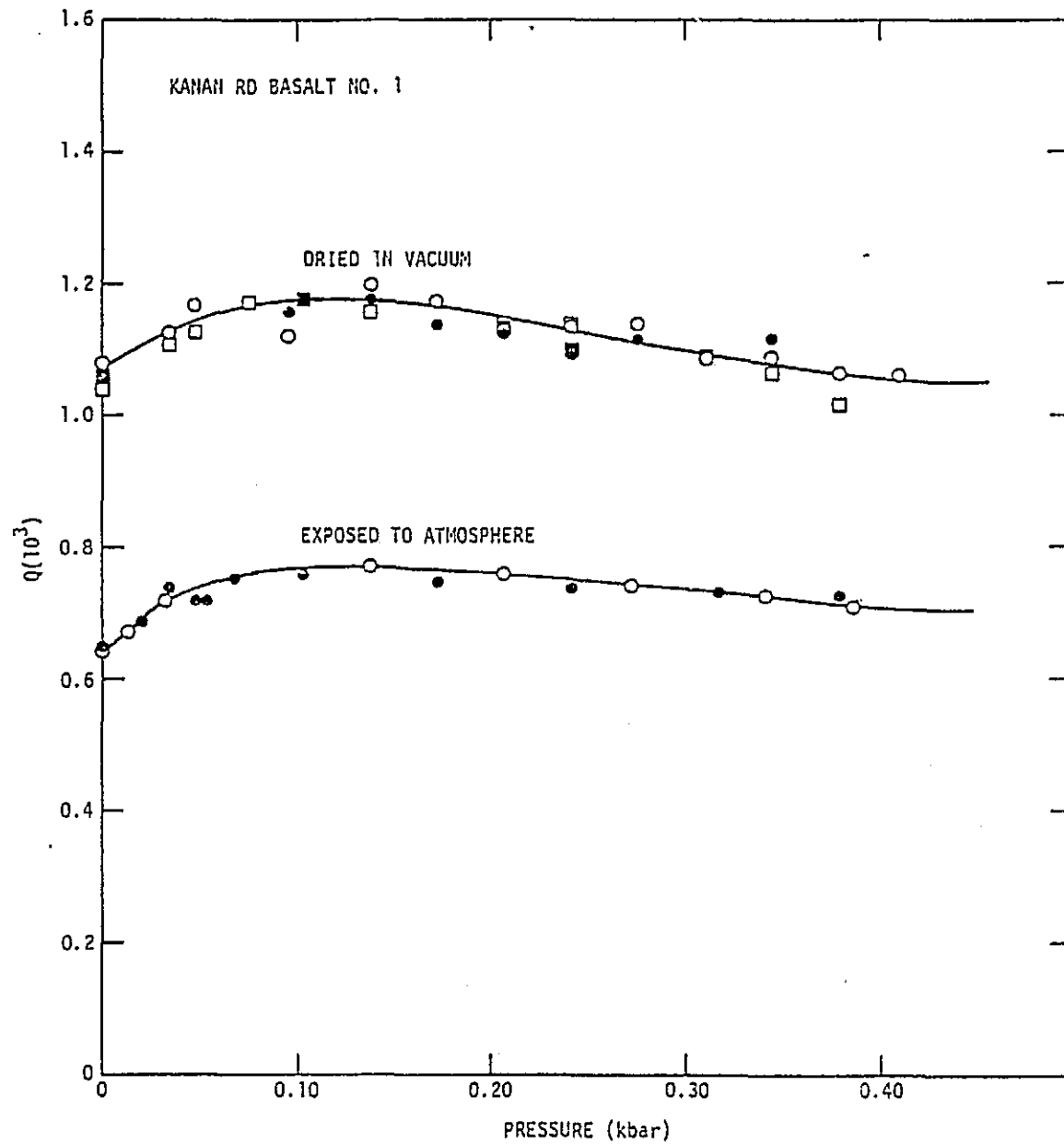


Fig. 1 Quality factor Q dependence on confining pressure for terrestrial analog of lunar basalt. Q measurements on Cu clad Al bars have established a background attenuation of $Q^{-1} < 10^{-4}$.